BACKGROUND

The bioclimatic chart originally developed by Victor and Aladar Olgyay in the 1950's has been revised as a result of additional research by: *Edward Arens*, Associate Professor, Department of Architecture, University of California, Berkeley; *Lufti Zeren*, Department of Architecture, Technical University of Istanbul; *Richard Gonzalez*, Associate Fellow, J. B. Pierce Foundation Laboratory and Associate Professor, School of Epidemiology, Yale University; *Larry Berglund*, Assistant Fellow, J. B. Pierce Foundation Laboratory and Lecturer, Department of Architecture, Yale University; and *Preston McNall*, Chief, Building Thermal and Service Systems Division, Center for Building Technology, National Engineering Laboratory, National Bureau of Standards, Washington, DC. Their work was supported by the Department of Energy.

This wall chart is based on their paper, *A New Bioclimatic Chart For Environmental Design*, presented to the International Congress on Building Energy Management at the May 1980 meeting in Portugal. The paper will be available soon through the authors.

FACTORS

This chart is based on three conditions — (1) the weight of clothing worn (2) the activity level of individuals and (3) the angle of the sun above a horizontal plane.

(1) Clothing — The insulating value of clothing is expressed in Clo values. 1.0 Clo, introduced by Gagge, is the insulating value of a man's business attire in 1941. A clothing level of 0.8 Clo was chosen for this chart to represent typical clothing for both males and females in the cool part of the year. It also represents a compromise between indoor and outdoor clothing. Further information on Clo values for common items of clothing can be found in "How To Be Comfortable at 65 to 68 Degrees". Nevins, McNall and Stolwijk, ASHRAE Journal April 1974. Reference points include the bikini at .05 Clo, open neck shirt and shorts at .4 Clo. Clothing combinations over 1.3 Clo tend to be too bulky for protracted indoor wear.

(2) Activity Level — 1.0 Met is the metabolic rate of the average resting adult. An activity level of 1.3 Met was chosen as representing typical levels of activity in home, outdoor, and even office environments. This level of 1.3 Met corresponds to light household work, to slow walking as is common in shopping indoors and outdoors, and to office work where the occupant is required to get up and move around occasionally.

(3) Sun Angle — A sun angle of elevation of 45° was chosen as representing a typical value obtainable at many times of year in large areas of the U.S.

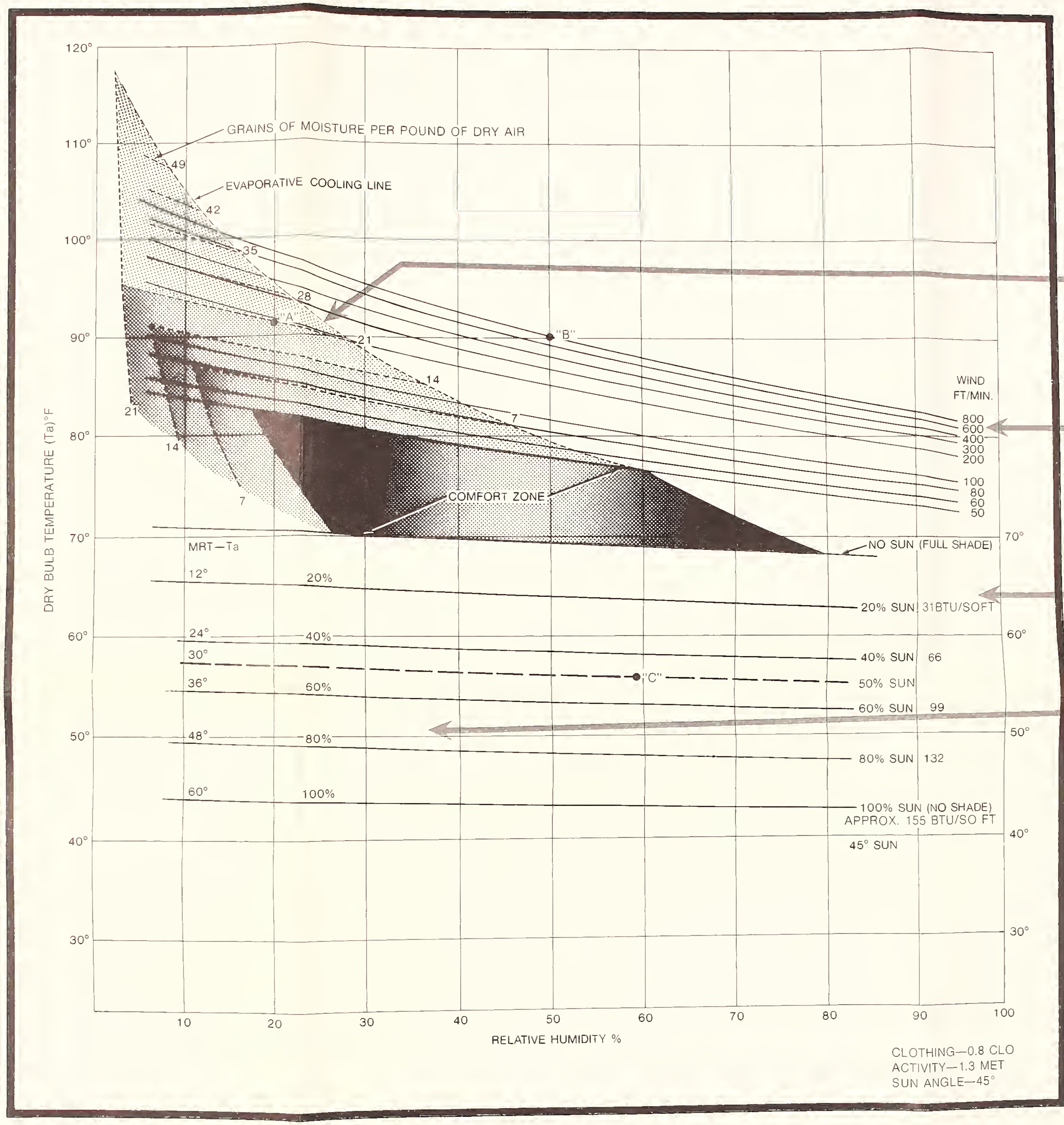
Other charts based on different values of clothing, activity and sun angle are anticipated in the future for wider application.

HOW TO USE THIS CHART

Eighty percent of people wearing .8 Clo, having a metabolic rate of 1.3 Met (light exercise) will be comfortable in still air at combinations of temperature and relative humidity lying within boundaries of the comfort zone. In that zone Mean Radiant Temperature (surrounding surface temperatures) are equal to the air temperature. Outside the comfort zone, the chart has contour lines, along which selected levels of radiation, air velocity, or evaporative cooling will restore a person's thermal sensation to the nearest boundary of the comfort zone. The radiation values offset temperatures that are too low, and the air velocity and evaporative cooling values offset temperatures that are too high. Combinations of radiation and air velocity are not considered, in order to reduce the complexity of the chart. The levels of radiation and air movement represented on the chart extend to extreme values that are normally only encountered outdoors, and as a consequence the range of temperatures considered is wide.

A design procedure based on the superposition of outdoor climate and occupant comfort requirements requires a close coupling between outdoors and the location of the occupants. This coupling exists in outdoor spaces, and in "envelope-dominated" buildings like residences where climate elements are available indoors in the form of sunshine through windows, natural ventilation, and thermal transfer through walls and roofs. This design procedure is not appropriate for those large commercial buildings that create their own internal climate entirely by means of mechanical systems.

As a result of the rise in energy costs and energy availability problems, there are now trends toward designing large commercial buildings that are more "envelope-dominated," and toward passive solar design in commercial scale buildings as well. Envelope-dominated buildings have one or more of the following characteristics: more building perimeter to obtain daylighting; more natural ventilation through windows, meaning higher air movement rates; direct solar gain into occupied spaces; high radiant temperature differences resulting from solar-heated components such as Trombe walls and floor slabs; localized radiant heating and fan cooling; and evaporative cooling.



BIOCLIMATIC CHART

DESIGN STEPS

A. Overlay the comfort chart with the average daily temperature and humidity amplitudes for selected months to determine when ventilation or radiation is needed.

B. Select the appropriate design element — SOLAR RADIATION, SURFACE RADIATION, AIR VELOCITY or EVAPORATIVE COOLING, and determine the amount needed to provide thermal comfort. See examples at each design element.

C. Utilize natural forces to provide needed radiation evaporative cooling or ventilation, and supplement these with mechanical means only as necessary.

EVAPORATIVE COOLING

High temperatures and low relative humidities can be made comfortable by evaporative cooling. Evaporative cooling is effective only in the shaded area to the left of the "evaporative cooling" line. For example, point "A," 91°F and 20% RH, would be restored to the upper boundary of the comfort zone in "still air" by treating the air with an evaporative cooler adding, on the average, 21 grains of water per pound of dry air to the environment.

AIR VELOCITY

Temperatures in the upper eighties and even in the nineties can be comfortable if the relative humidity is not high and there is a breeze, either natural or from a fan. The air velocity lines describe the upper limits of comfort at various humidities and air velocities.

Example: Point "B", 90°F and 50% R.H., is comfortable with an air velocity of 800 feet per minute, about 9 mph. Point "B" will fall outside the comfort zone if the air velocity drops below 800 feet per minute.

SOLAR RADIATION

Temperatures as low as the middle forties are comfortable under the full effects of a 45° sun. Above this temperature provide shading as required to avoid overheating.

Example: Point "C," 56°F and 60% RH, is comfortable with approximately a 50% sun.

SURFACE RADIATION

Surfaces that are warmer than the surrounding air temperature can have a warming effect similar to the sun. This difference between the Mean Radiant Temperature (MRT) and air temperature is shown on the chart as MRT-Ta.

Small differences, in the range of 10 to 15 degrees, can be expected from previously absorbed solar radiation. Higher differences can be achieved with special solar radiation absorbing devices or with conventional hot water, steam or electric resistance heaters.

Example: Again at Point "C," 56° and 60 RH, is comfortable with radiation from nearby surfaces whose mean radiant temperature (MRT) is 30.5°F above the air temperature of 56°F. A large surface at a temperature of 150-200°F would be required, since it would be impractical to heat **all** surfaces surrounding a person to 86°F.

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Issued May 1980

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